Teknologiateollisuus

VALUN KÄYTÖN SEMINAARI 2026

From Design to Manufacturing:
How AI Is Transforming Engineering Workflows

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Tampere University

D2M
Digital Design & Manufacturing

… Keynote overview

from challenge to actionable insights

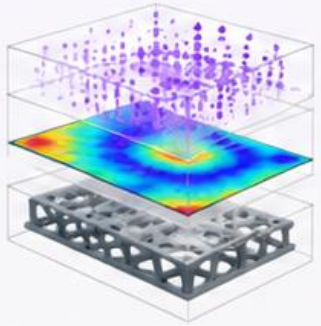
1 The challenge

Why D²M and what we aim to achieve.



2 The methods

Experiments, modelling, and optimization.



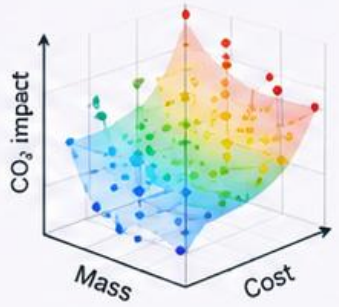
3 Process evidence

Insights from manufacturing experiments.



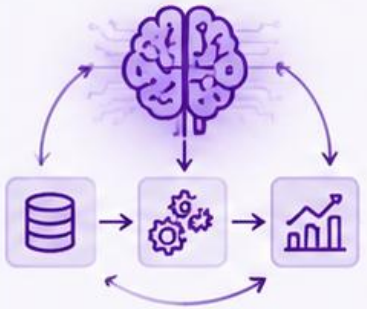
4 System trade-offs

Performance, manufacturability, and sustainability.



5 AI-enabled workflows

From data to decisions across scales.



6 Conclusion

Key takeaways and next steps.

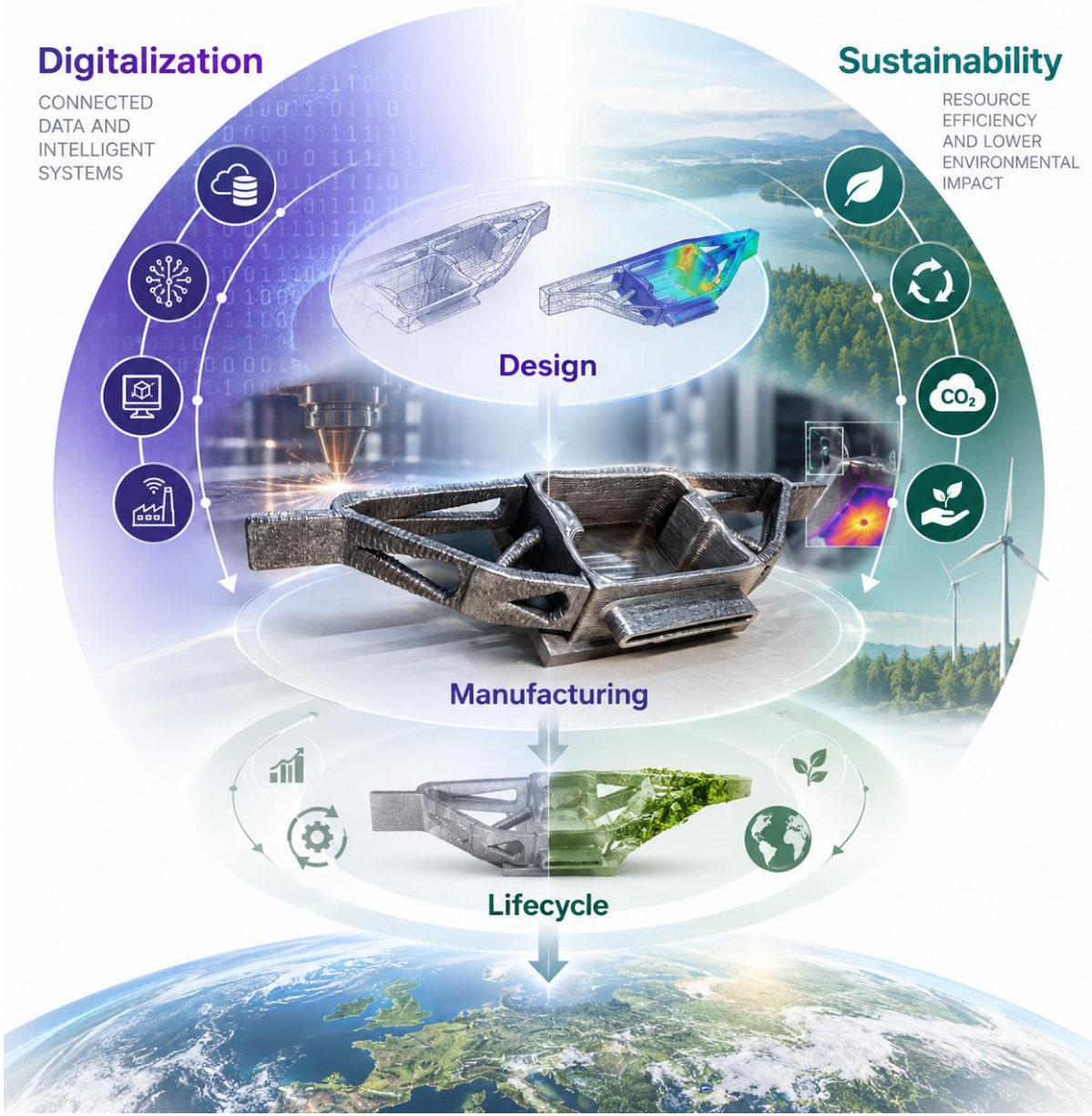


Twin-transition in Engineering Design and Manufacturing

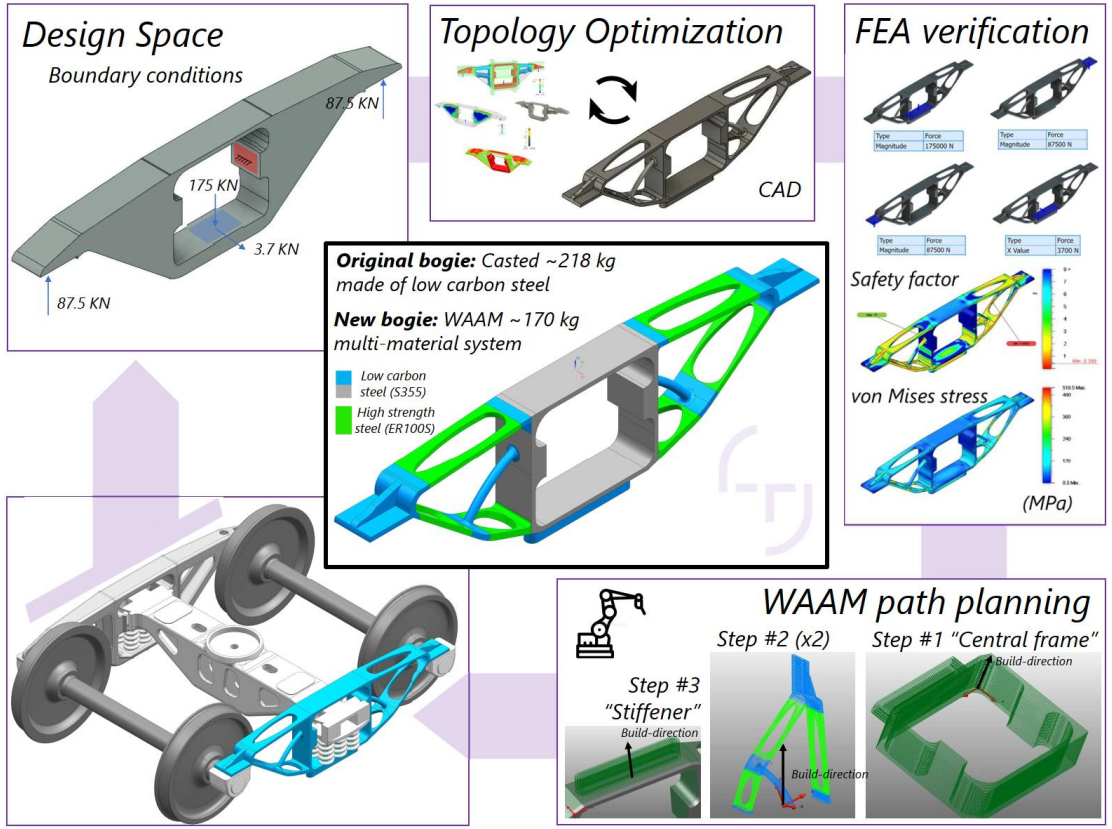
Manufacturing is a major contributor to the global economy, energy consumption, and carbon emissions.

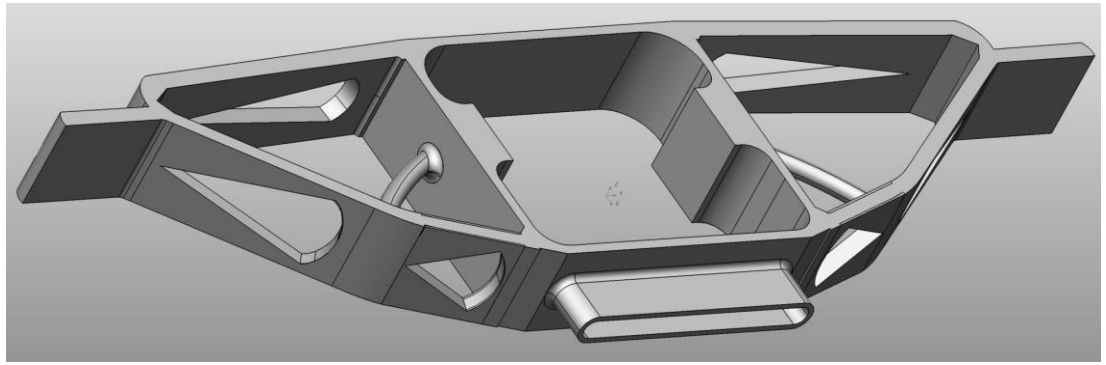
The twin transition (digitalization and sustainability) requires better integration of materials, design, manufacturing, and supply chains.

Connected data and intelligent systems enable more efficient, sustainable, and increasingly autonomous engineering decisions.



From design to manufacturing





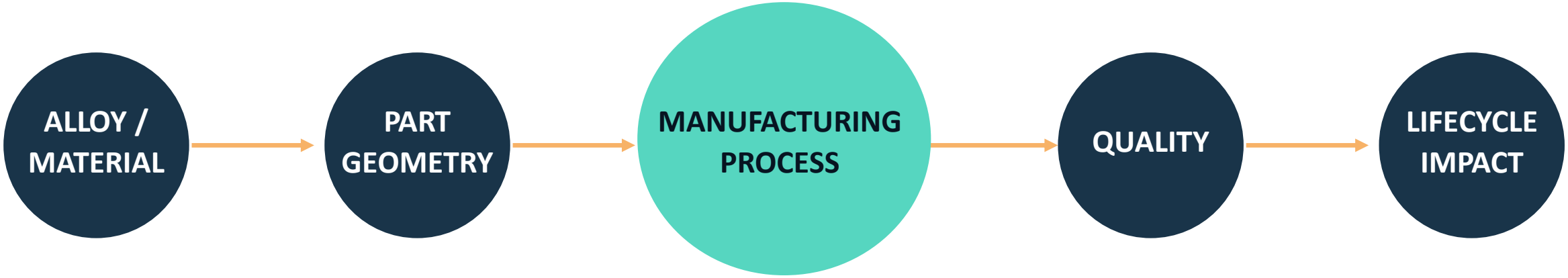


One component. Many connected decisions



- **MATERIAL**
  Properties and sourcing
- **GEOMETRY**
  Performance and weight
- **PROCESS**
  Feasibility and variation
- **QUALITY**
  Verification and defects
- **IMPACT**
  Energy and lifecycle

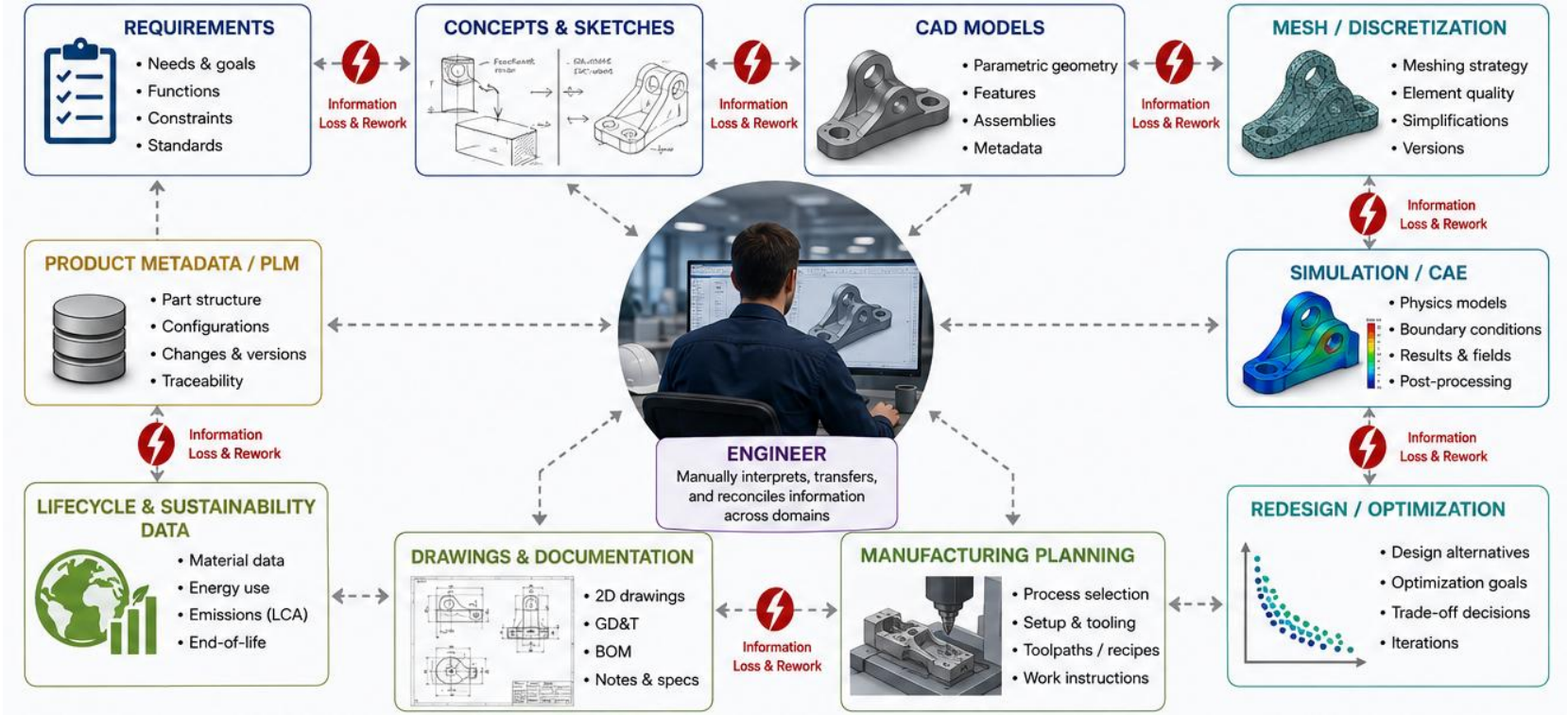
A change in one domain propagates everywhere



Constraints and feedback travel in both directions

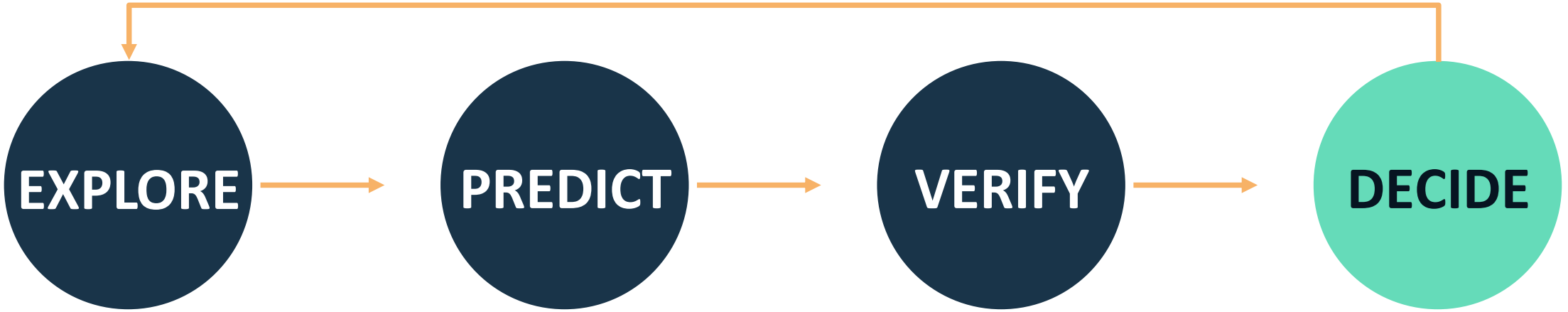
Local improvements can create system-level compromises.

Powerful tools: Fragmented workflows



Humans manually translate and reconcile engineering information.

The next step: Connect the decision loop



What are the possible alternatives?

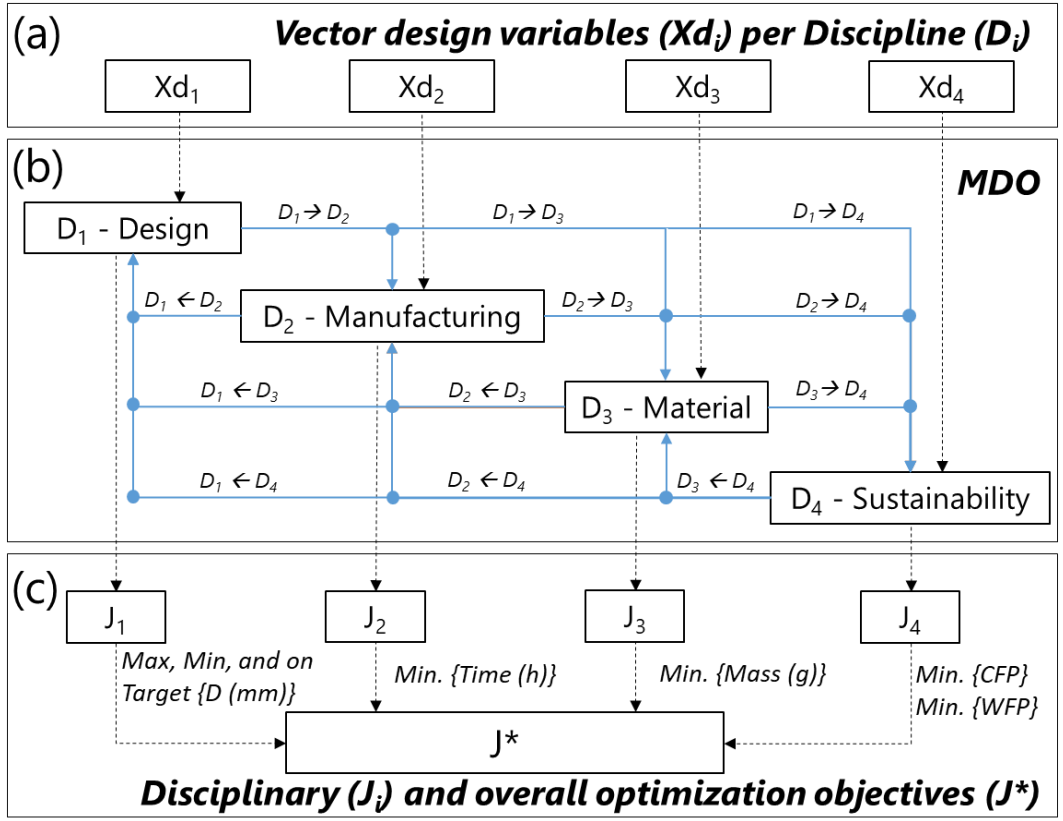
What happens if we change X?

Does it satisfy physical constraints?

Which trade-off is acceptable?

Human expertise remains the acceptable authority.

Design-to-Manufacturing: Multidisciplinary links



1 **CONNECTED DOMAINS**
Design, manufacturing, material selection and sustainability.

2 **COUPLED ENGINEERING MODELS**
Shared variables, responses and constraints create dependencies.

3 **DISCIPLINARY OBJECTIVES**
Local goals contribute to system-level performance.

4 **SURROGATES FOR EFFICIENCY**
Validated approximations accelerate costly evaluations.

5 **INTEGRATED OPTIMIZATION**
Identify feasible trade-offs across all disciplines.

Optimize the system—not each discipline in isolation.

Model- and data-driven engineering

MODEL-DRIVEN (MD)

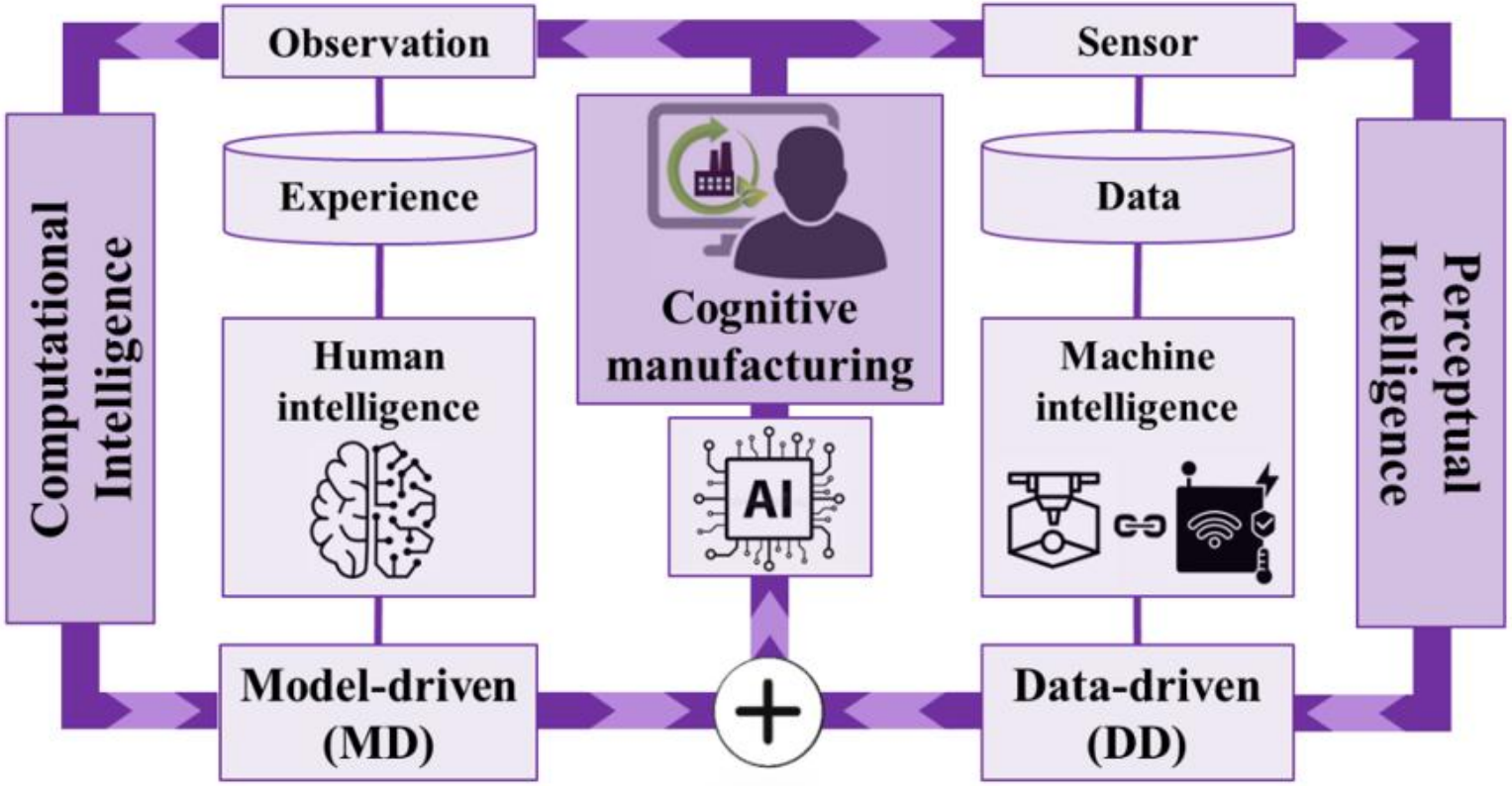
Physical and numerical models explain mechanisms and constraints.

DATA-DRIVEN (DD)

Experiments, sensors and production data reveal useful relationships.

TOGETHER

Combine physical reasoning and measured evidence—then validate predictions.

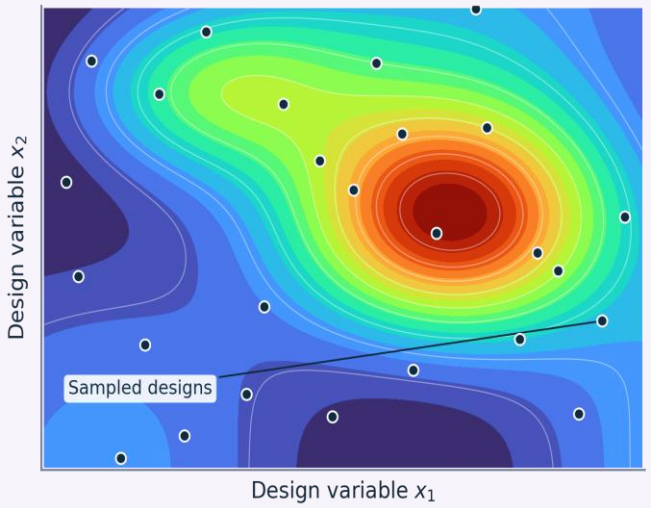


KEY POINT **Trust requires independent validation within a defined operating range.**

From design space to decisions

EXPLORE

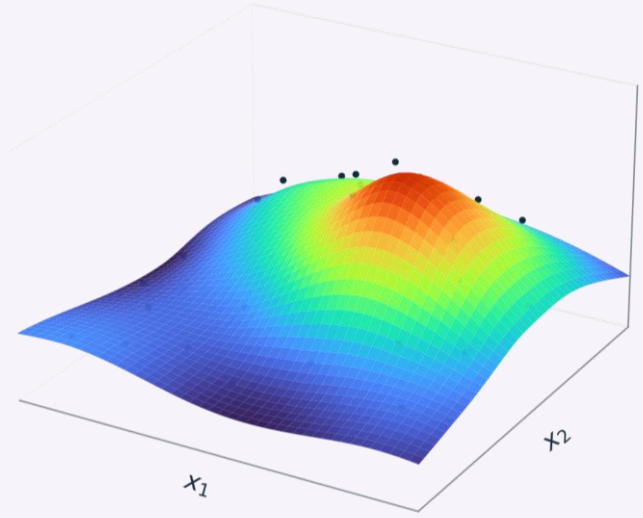
What is possible?



Sample broadly to reveal sensitivities and promising regions.

APPROXIMATE

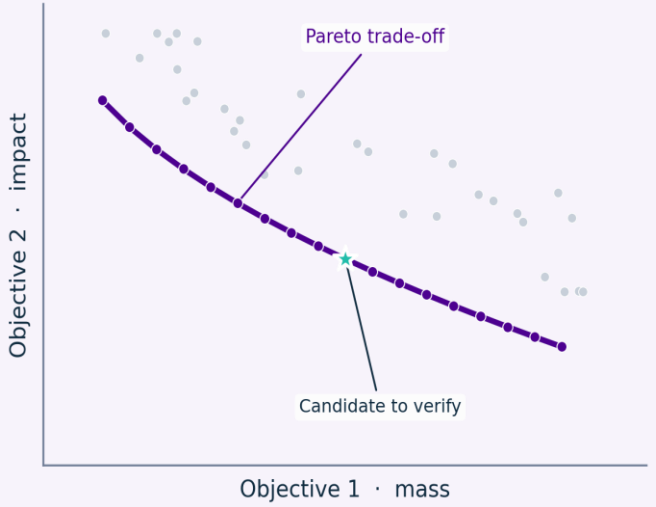
What will happen?



Use surrogate models for fast predictions—with error and uncertainty checks.

OPTIMIZE

Which design to choose?



Search Pareto trade-offs under constraints; verify candidates.

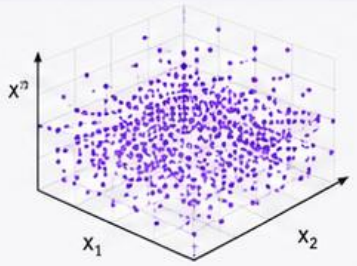
A mathematical optimum becomes an engineering decision only after feasibility and independent validation.

Methodological tools and workflow

Virtual & physical Design of Experiments (DOEs)

Explore and generate data (e.g., OFAT, factorial designs, RSM, Latin hypercube, …)

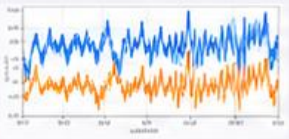


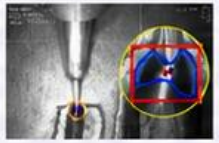


Data-driven (DD) methods

Process data and perceptual intelligence

- In-process monitoring (sensors, images)
- Machine learning and surrogate models
- Property measurement and analytics

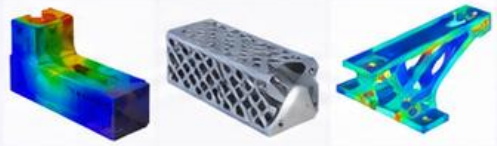




Model-driven (MD) methods

Physics-based and numerical modelling

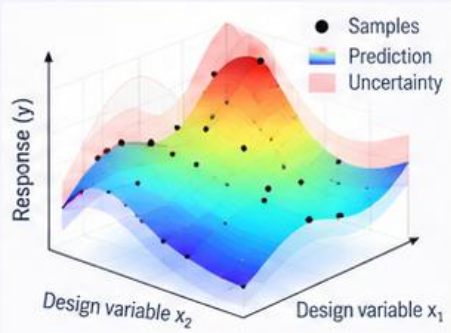
- Multi-fidelity simulations (FEM, CFD, …)
- Process and part scale models
- Generative design and topology optimization



Coupled-hybrid modelling

Integrate physics and data

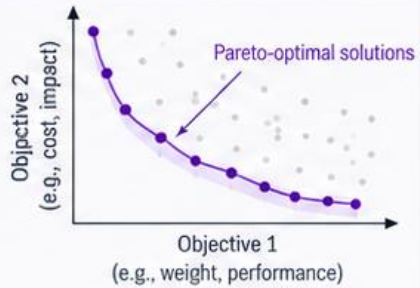
- Data-driven surrogates (e.g., regression, RSM, GP, DNN, …)
- Physics-informed models (e.g., reduced order models, …)
- Uncertainty quantification (e.g., sensitivity analysis, Monte Carlo, Bayesian, …)



Optimization

Find the best solutions under constraints

- Process integration and design optimization (e.g., PIDO, multidisciplinary)
- Multi-objective optimization (e.g., Pareto methods)
- Global search methods (e.g., GA, PSO, …)
- Constraint handling (feasibility, manufacturability, …)



Cognitive Design to Manufacturing Systems

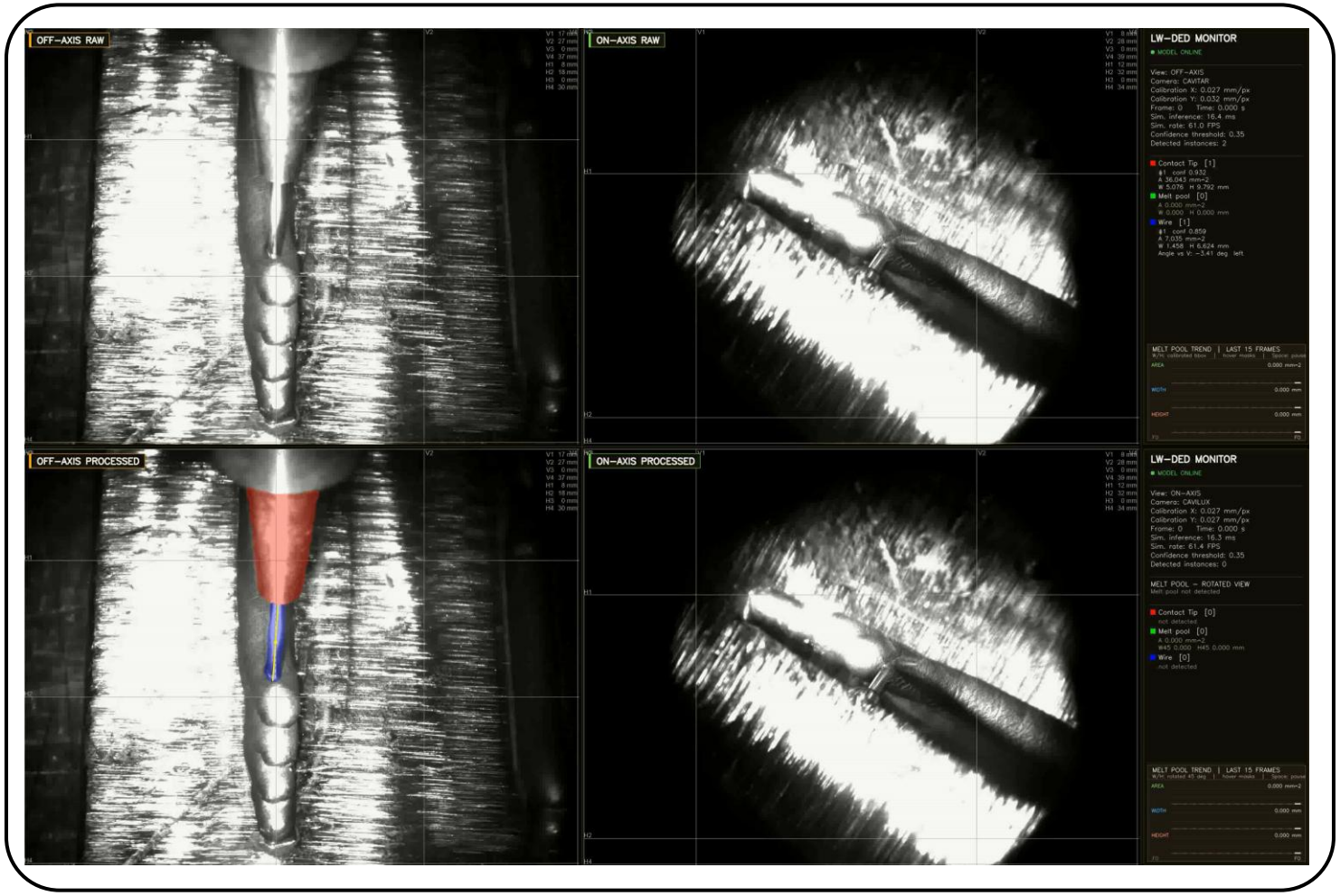
Decision support and deployment

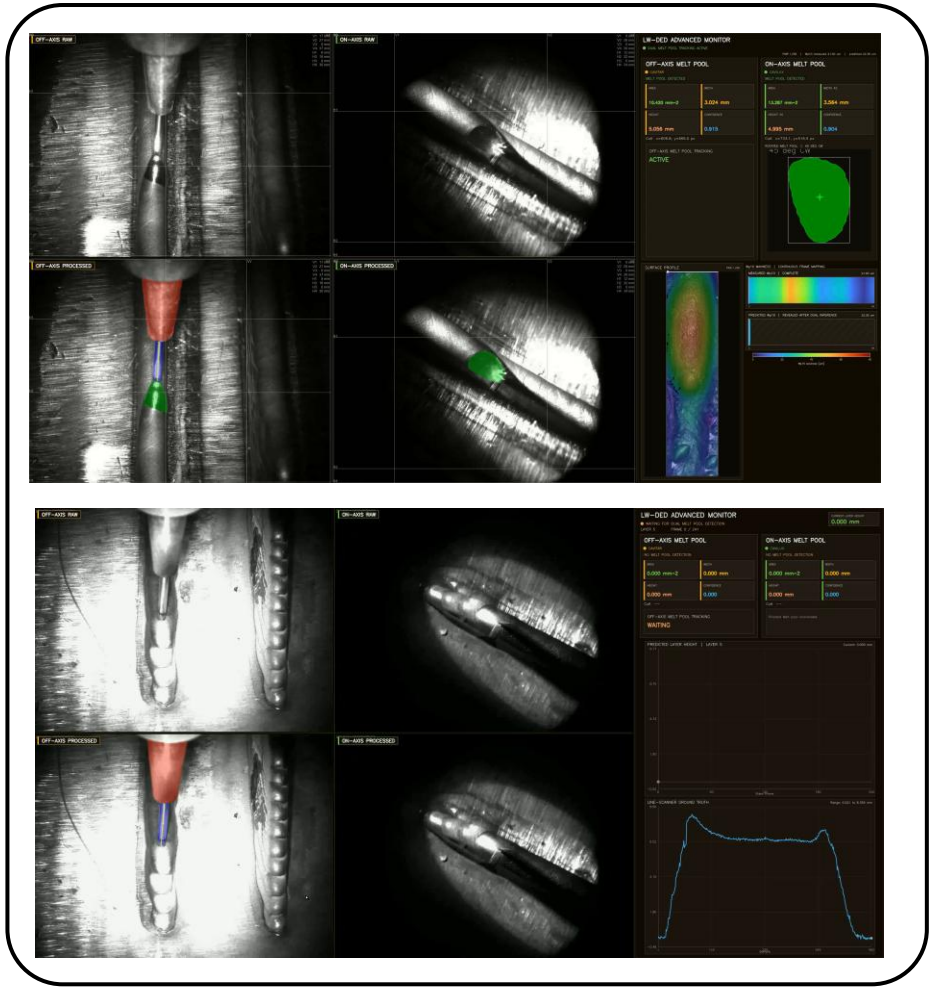
- Compare and validate alternatives
- Evaluate feasibility, reliability and sustainability
- Support engineering decisions
- Link to manufacturing systems



Iterative workflow
New evidence improves models and decisions

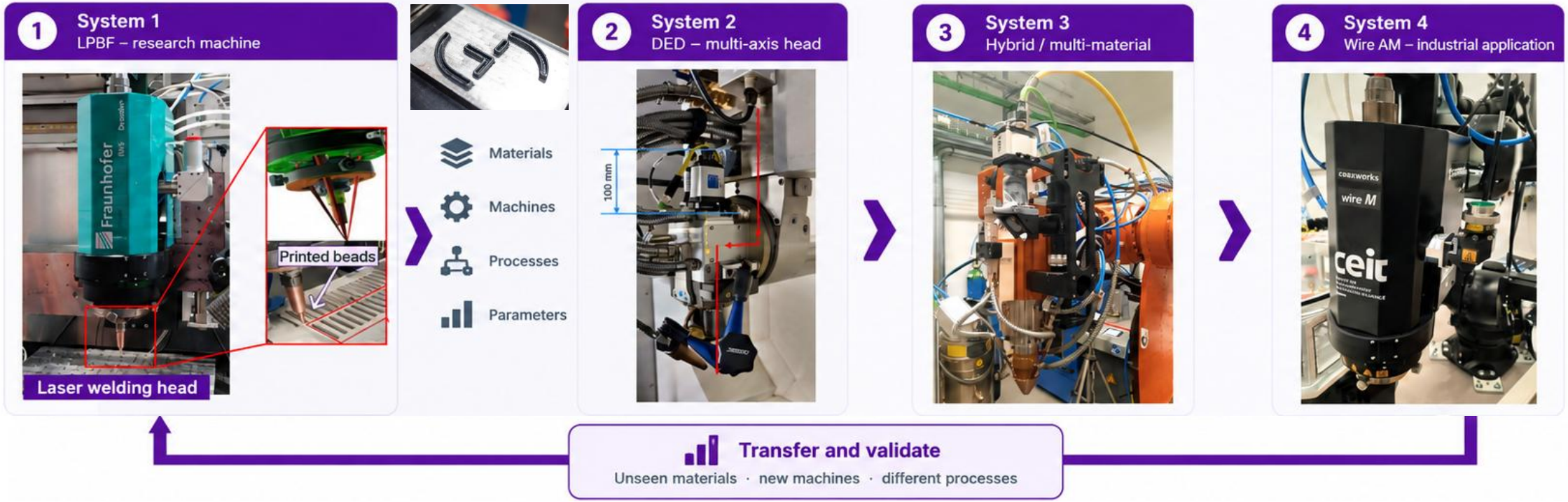
Research example: Seeing inside manufacturing



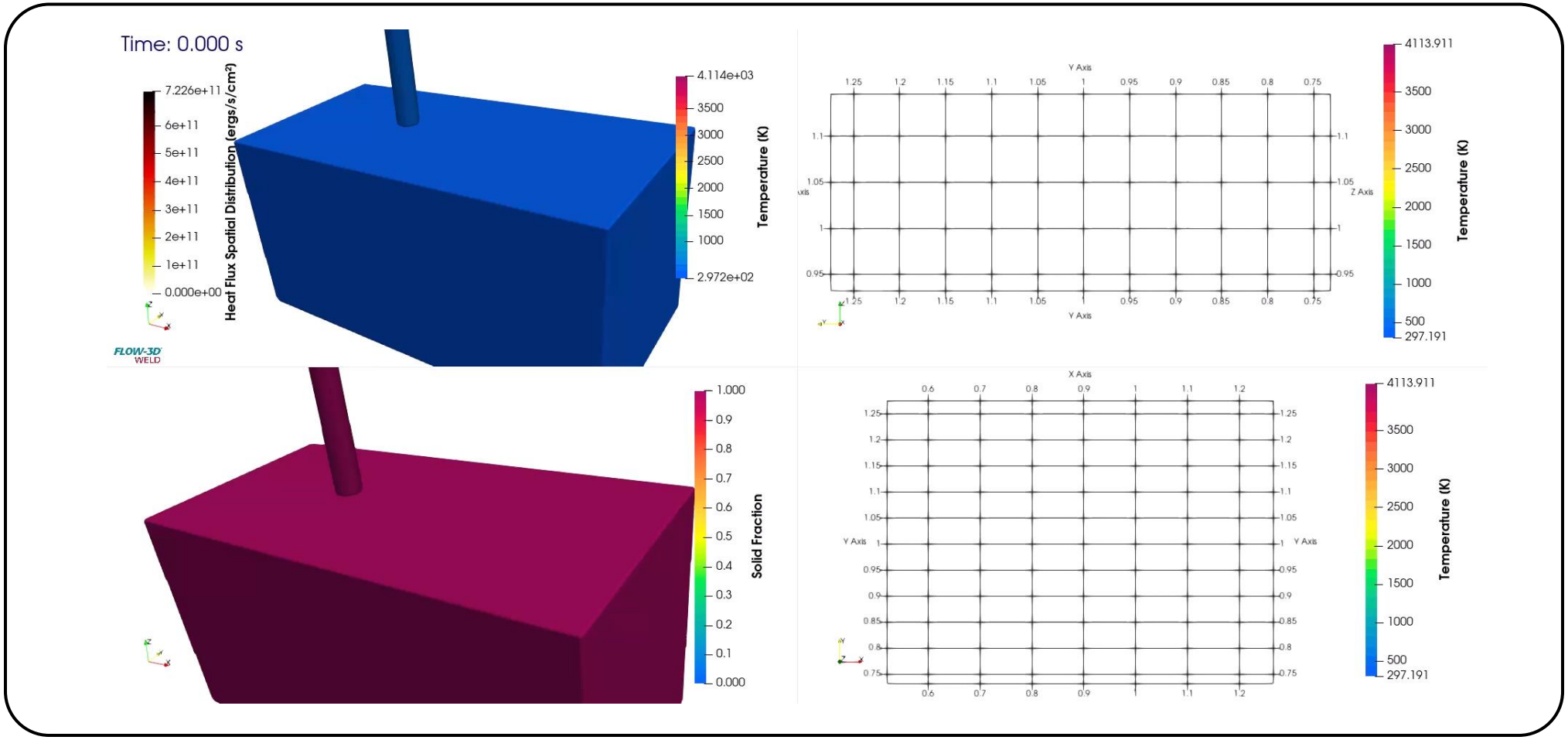


Combining model- and data-driven manufacturing methods

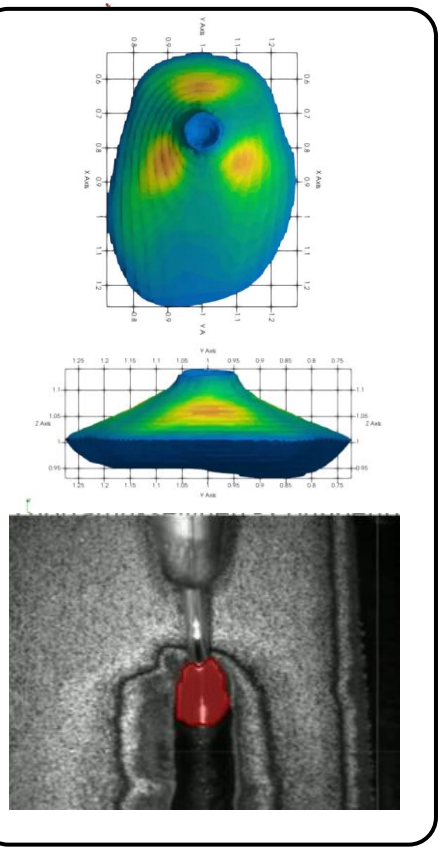
Transfer across materials / machines / processes' and 'test on unseen domains.

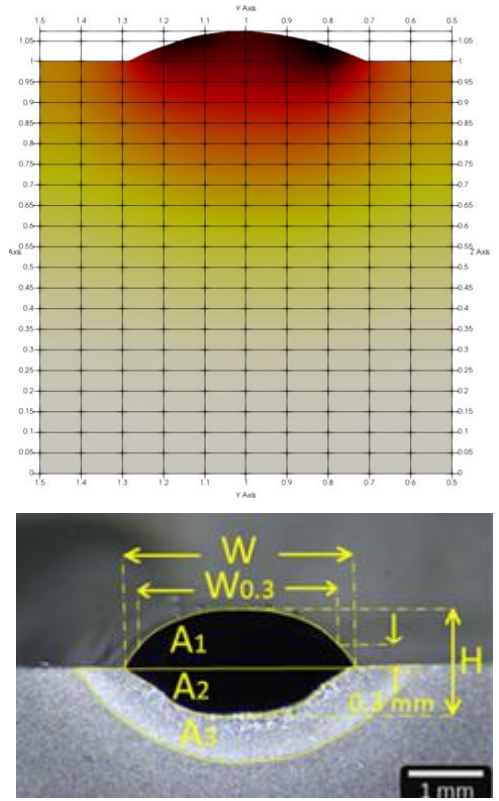


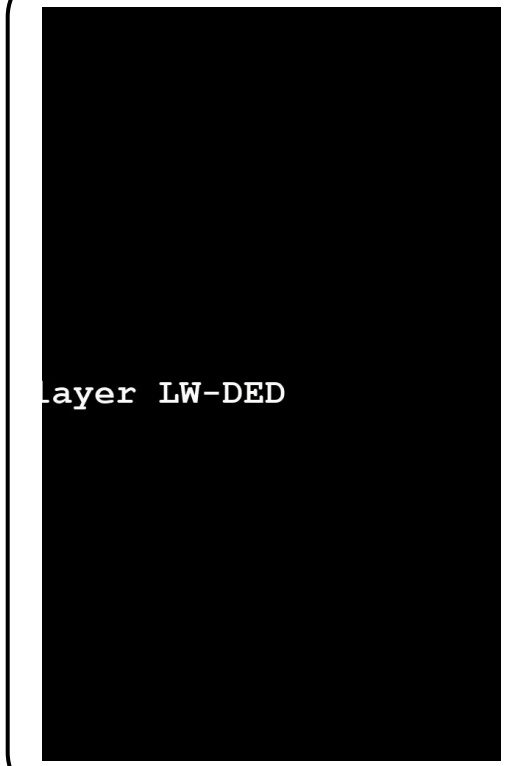
Physics explains mechanisms

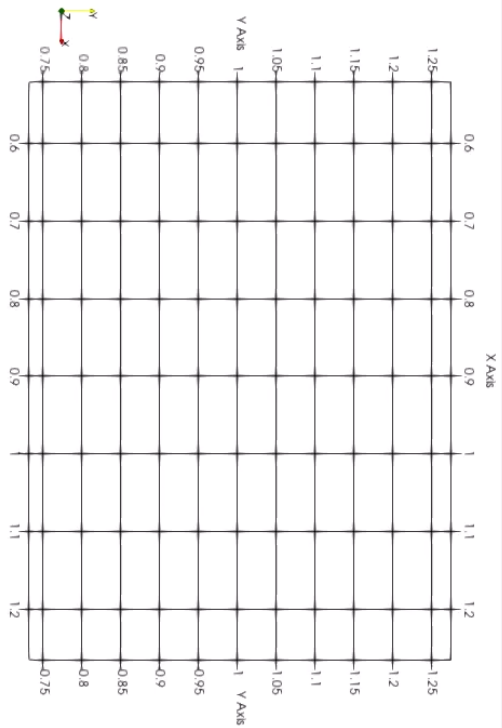


Physics explains → Data observes → Models predict

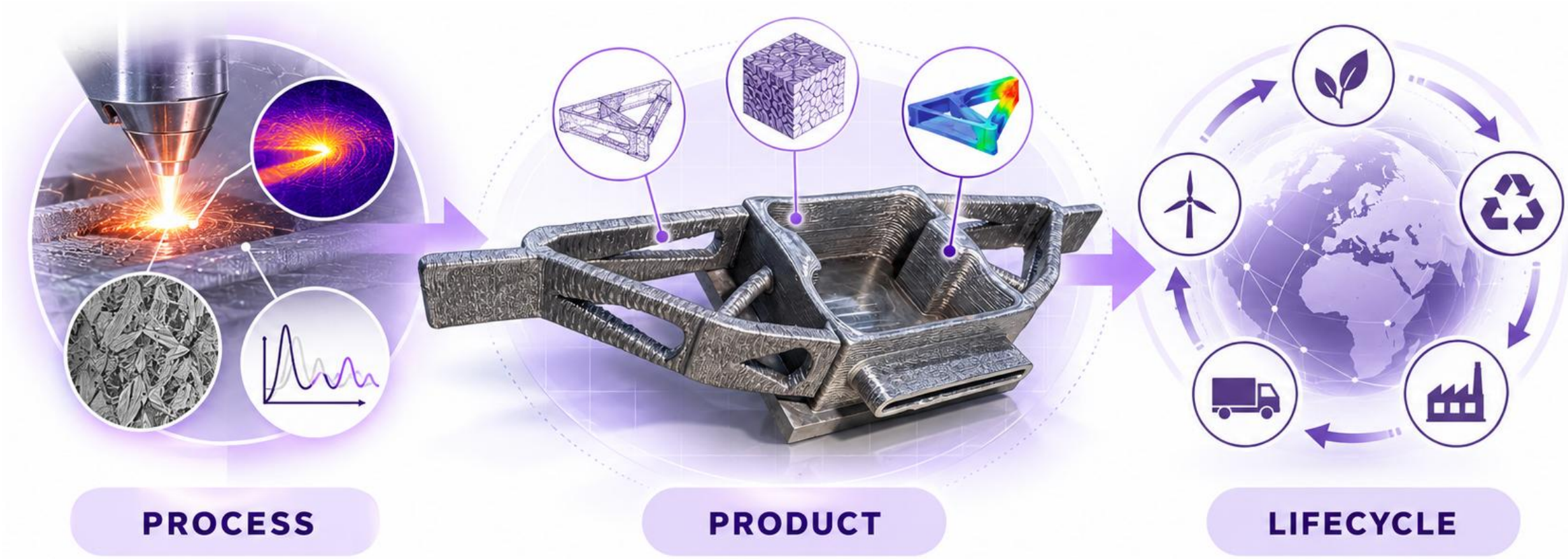






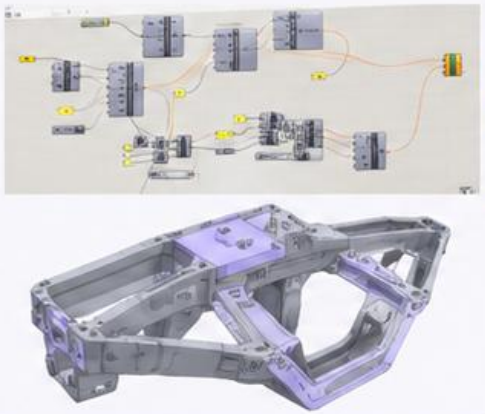


Bringing scales

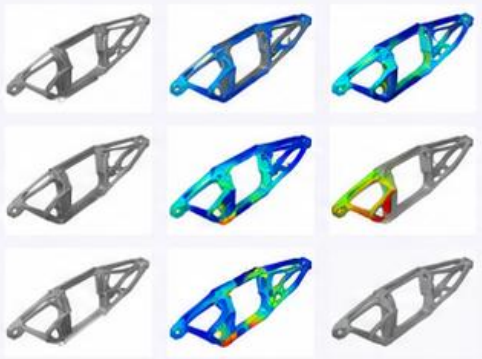


Scaling: from process to product

1 Design variables
250+ parameters

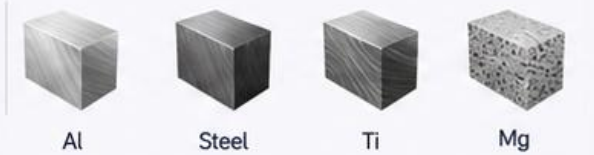


2 Design exploration
80+ generated alternatives

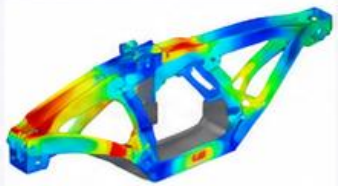


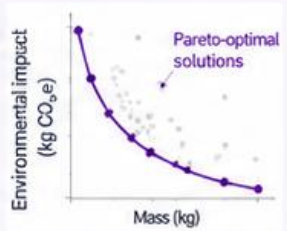
3 Process and material options
3 manufacturing methods
and 4 material combinations

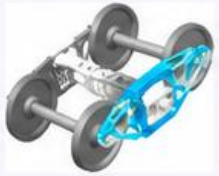


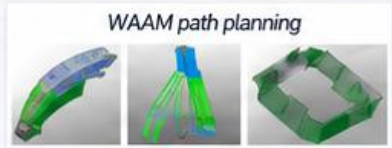


4 Product verification and planning
Performance, manufacturability
and sustainability



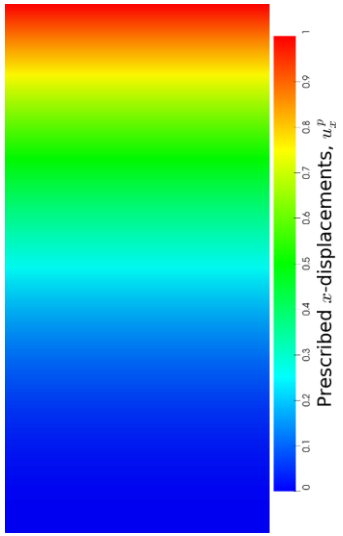




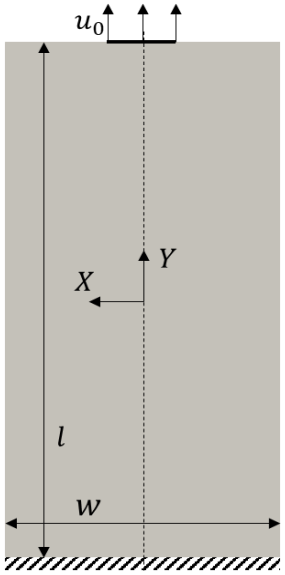


Scaling: from process to product

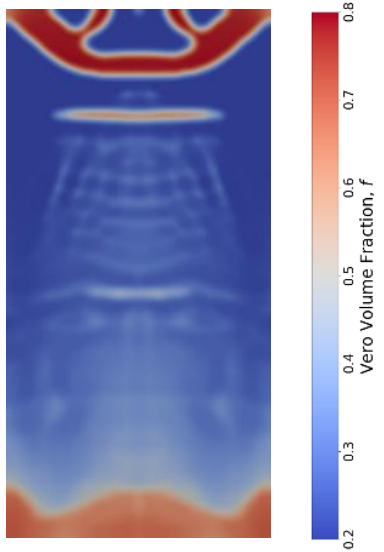
Programed displacement map



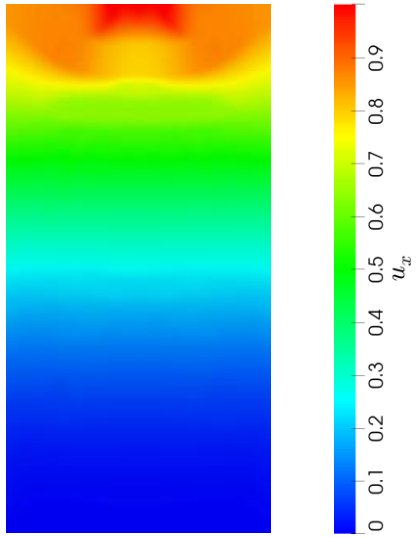
FE – Design automation

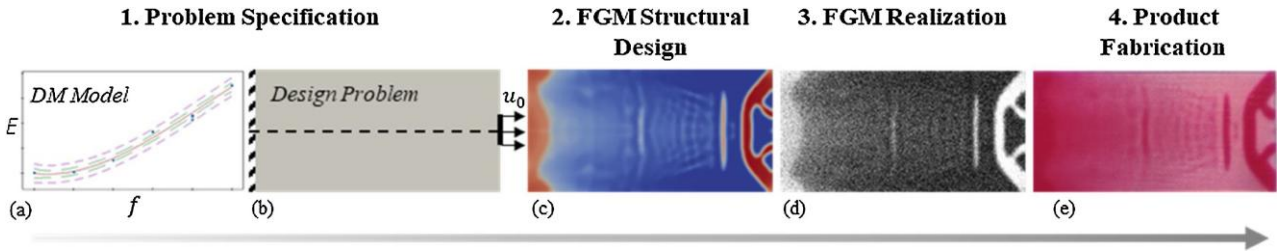


Optimal distribution

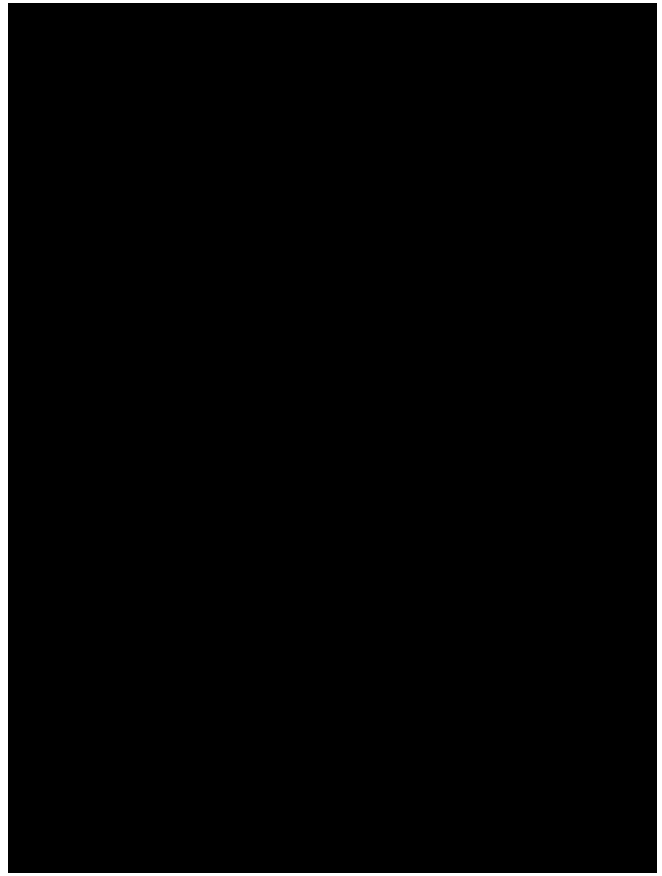


FE – Result

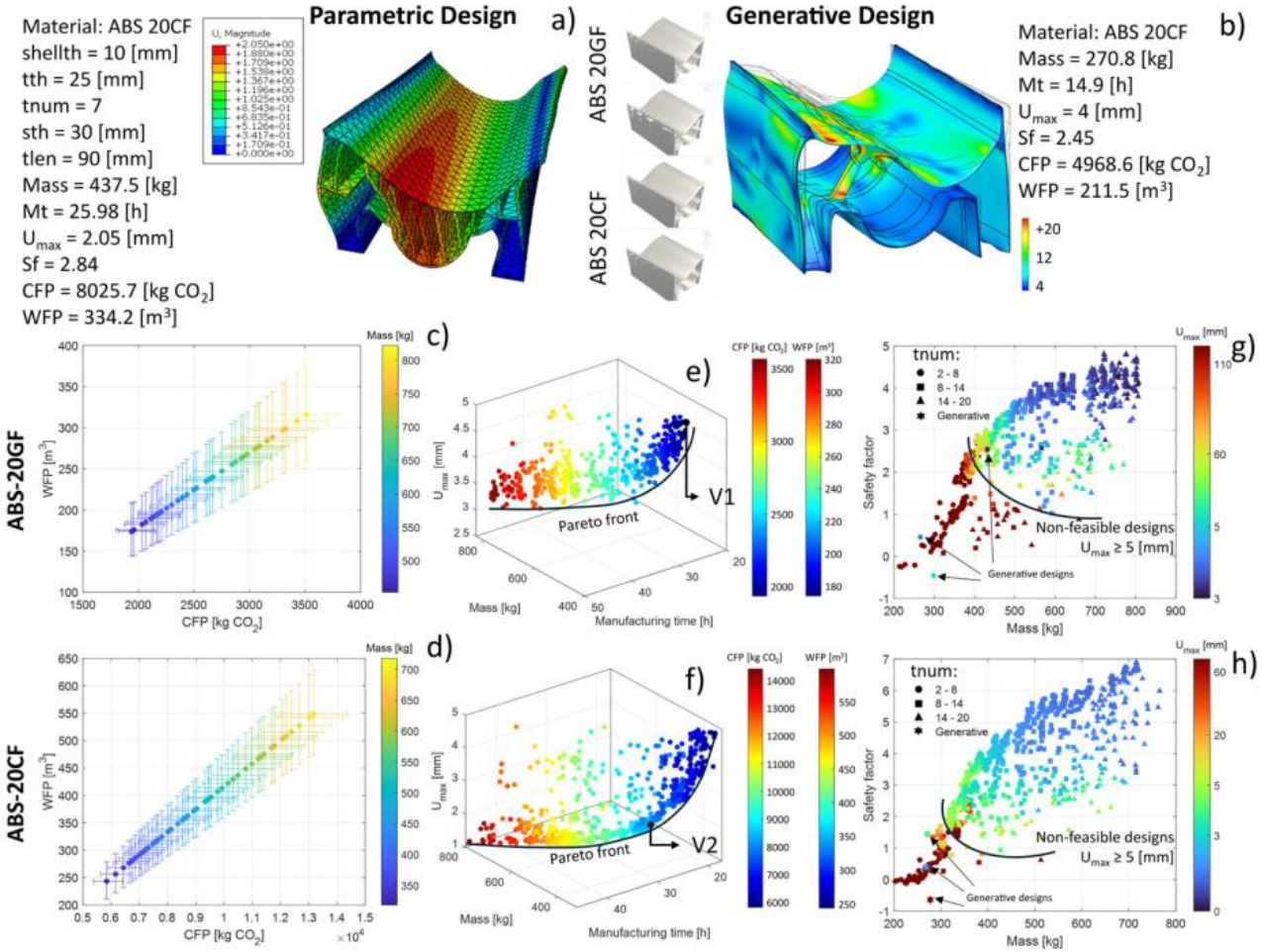




DIC – Validation



Scaling: product to impact



01 LIGHTER IS NOT ALWAYS GREENER

Lower mass does not automatically mean lower lifecycle impact.

02 MATERIAL CHOICE SHIFTS IMPACT

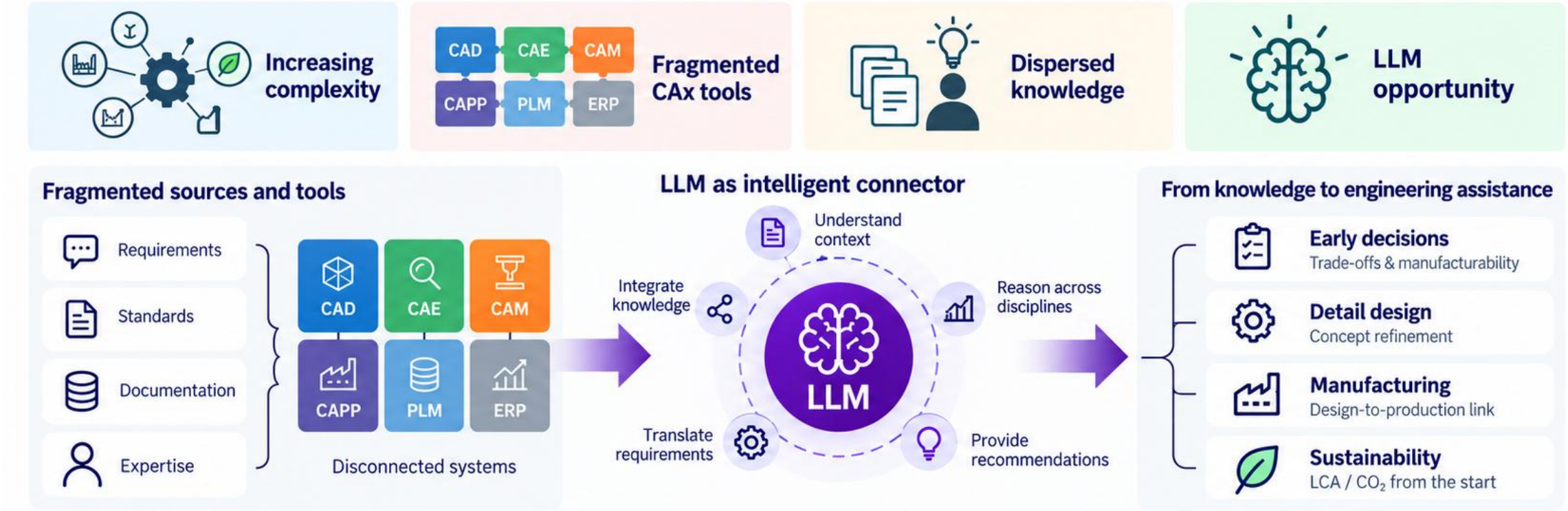
Carbon fibre improves structural performance, but here increases carbon and water footprints versus glass fibre.

03 DESIGN STRATEGY MATTERS

Parametric design handles constraints; generative design explores broader alternatives.

Optimize performance and impact together.

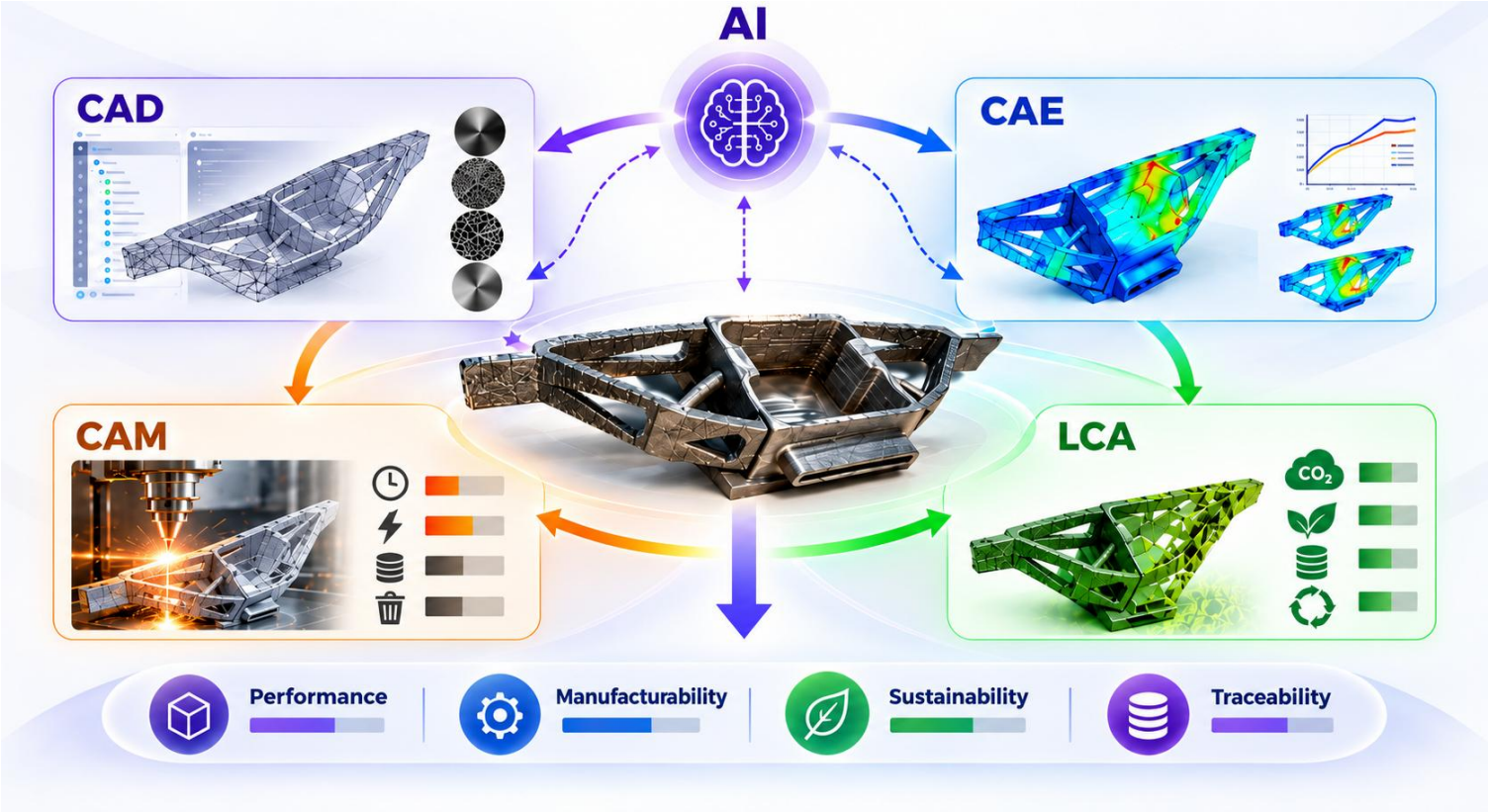
Gen - AI as orchestrator: not as physics



KEY POINT

LLM/VLMs connect fragmented engineering information into actionable decision support
Gen AI orchestrates the workflow; validated engineering models establish trust

Next-Generation of Computer Aided Systems (CAx)



PERFORMANCE + SUSTAINABILITY

- Connect CAD–CAE–CAM outputs to energy, carbon and resource indicators.
- Evaluate performance and lifecycle trade-offs from early design.

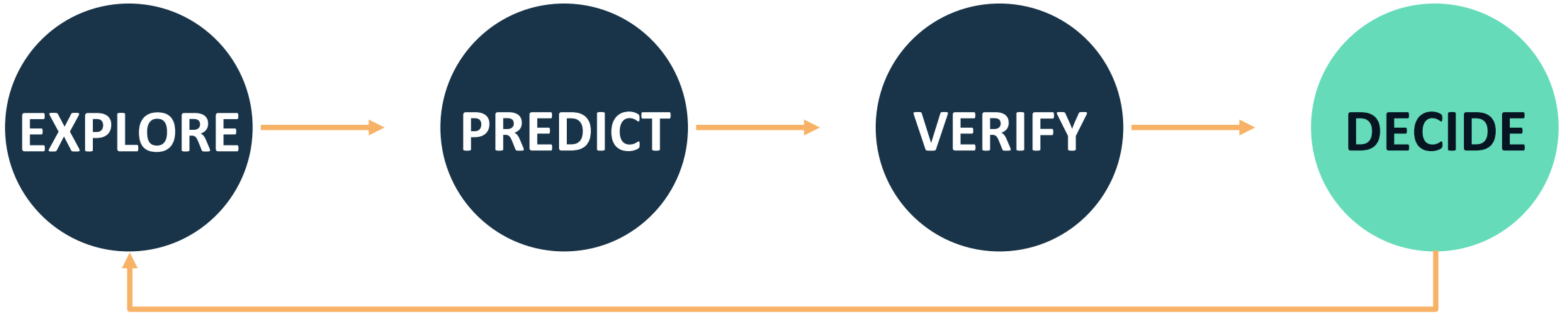
FUTURE RESEARCH

- Assemblies and multi-stage manufacturing chains.
- Test surrogate generalization and reuse.
- AI-supported, verifiable decisions.

Where should a foundry start?



FROM CONNECTED WORKFLOWS TO CONNECTED DECISIONS



AI Coordinates → Engineering models verify → People remain accountable

Thanks



Antti Martikkala (Post-doctoral researcher)

Skills: *Open-source IoT, Interoperability in IoT*



Antoine Queguineur (Post-doctoral researcher)

Skills: *Welding, AM, material science, manufacturing*



Arturo Rubio Ruiz (Post-doctoral researcher)

Skills: *CAx, data-informed engineering, fatigue*



Reza Asadi (Doctoral researcher)

Skills: *Intelligent manufacturing, AI*



Amirmohammad Daareyni (Doctoral researcher)

Skills: *Computational mechanics, machine learning*



Reza Shahzadi (Doctoral researcher)

Skills: *Composite materials, Multi-scale modeling*



Lasse Känsälä (Researcher)

Skills: *Generative AI, Multi-agent systems*



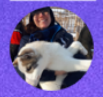
Arron Thompson (Researcher)

Skills: *Hardware and software prototyping*



Olli Wiikinkoski (Researcher)

Skills: *Mechatronic prototyping*



Ashley Batesole (Researcher)

Skills: *AI, Multi-agent systems, Ontologies*

Iñigo Flores Ituarte
(Professor in Digital Manufacturing)- Group leader



Teknologiateollisuus

VALUN KÄYTÖN SEMINAARI 2026

Tampere University

D²M
Digital Design & Manufacturing

Research Council of Finland

Academy Research Fellow: Multidisciplinary Digital Design and Manufacturing (D2M) - Grant (346874)

organic

Funded by the European Union

Biological transformation of Additive Manufacturing Processes for the Sustainable Manufacturing of Bio-inspired products (ORGANIC) - Grant (101178127),